Malaria Journal

BioMed Central

Research

Open Access

Evaluation of Olyset™ insecticide-treated nets distributed seven years previously in Tanzania

Adriana Tami[1,2], Godfrey Mubyazi[3], Alison Talbert[4], Hassan Mshinda[2], Stéphane Duchon[5] and Christian Lengeler*[1]

Address: [1]Swiss Tropical Institute, P.O. Box, 4002 Basel, Switzerland, [2]Ifakara Health Research and Development Centre, P.O. Box 53, Ifakara, Tanzania, [3]National Institute for Medical Research, P.O. Box 81, Muheza, Tanzania, [4]Mvumi Hospital, P.O. Box 32, Mvumi, Tanzania and [5]LIN-IRD, 911 Av. Agropolis, BP 64501, 34394 Montpellier Cédex 5, France

Email: Adriana Tami - adriana.tami@lshtm.ac.uk; Godfrey Mubyazi - mubyazig@hotmail.com; Alison Talbert - alison_talbert@yahoo.co.uk; Hassan Mshinda - hmshinda@ifakara.mimcom.net; Stéphane Duchon - duchon@mpl.ird.fr; Christian Lengeler* - christian.lengeler@unibas.ch

* Corresponding author

Published: 29 June 2004

Malaria Journal 2004, **3**:19 doi:10.1186/1475-2875-3-19

Received: 04 March 2004
Accepted: 29 June 2004

This article is available from: http://www.malariajournal.com/content/3/1/19

Abstract

Background: Insecticide-treated nets represent currently a key malaria control strategy, but low insecticide re-treatment rates remain problematic. Olyset™ nets are currently one of two long-lasting insecticidal nets recommended by WHO. An assessment was carried out of the effect of Olyset™ nets after seven years of use in rural Tanzania.

Methods: A survey of Olyset™ nets was conducted in two Tanzanian villages to examine their insecticide dosage, bioassay efficacy and desirability compared with ordinary polyester nets.

Results: Of 103 randomly selected nets distributed in 1994 to 1995, 100 could be traced. Most nets were in a condition likely to offer protection against mosquito biting. Villagers appreciated mainly the durability of Olyset™ nets and insecticide persistence. People disliked the small size of these nets and the light blue colour and preferred a smaller mesh size, features that can easily be modified. At equal price, 51% said they would prefer to buy an Olyset™ net and 49% opted for an ordinary polyester net. The average permethrin content was 33%-41% of the initial insecticide dose of 20,000 mg/Kg. Bioassay results indicated high knock-down rates at 60 minutes, but the mosquito mortality after 24 hours was rather low (mean: 34%). No significant correlation was found between bioassay results and insecticide concentration in and on the net.

Conclusions: Olyset™ nets are popular, durable and with a much longer insecticide persistence than ordinary polyester nets. Hence, Olyset™ nets are one of the best choices for ITN programmes in rural malaria-endemic areas.

Background

Tanzania, with its 34 million people, carries a heavy malaria disease burden with an estimated 16 million clinical episodes per year and 100,000 child deaths [1]. In order to address this enormous burden, the country recently launched a national insecticide-treated nets (ITNs) initiative with the aim of protecting 60% of all children and pregnant women by 2007 [1]. Globally, ITNs were shown to substantially reduce morbidity and mortality from malaria in numerous settings [2] and they are currently deployed on a large scale in many malaria-endemic countries.

One of the main programmatic issues affecting ITN programmes is the necessity to re-treat regularly all the nets. For a number of reasons (such as washing, wear and tear, UV light and others) the pyrethroid insecticide on mosquito netting wears off over time and has, therefore, to be replaced. While it is relatively easy to socially market mosquito nets to the population of endemic countries, the idea of a regular insecticide re-treatment has been found very difficult to implement [3-5]. As a result, re-treatment rates have rarely risen above 20%, except in the frame of scientific trials or in settings such as China or Vietnam where re-treatment was carried out free of charge by government services. In Tanzania, social marketing programmes relying on insecticide kits sold through shops have also experienced low re-treatment rates [5,6].

An obvious solution to this problem is the development of netting that would be treated in such a way during manufacture so that it would not require any further insecticide treatment – a so-called "long-lasting insecticidal net" or LLIN [7]. So far there are two LLIN on the market that are recommended by the WHO Pesticide Testing Scheme (WHOPES): Olyset™ (Sumitomo Chemicals Co., Ltd., http://www.sumitomo-chem.co.jp) and PermaNet™ (Vestergaard Frandsen A/S, http://www.vestergaard-frandsen.com). Several insecticide and net manufacturers are active in developing long-lasting net technology. Olyset™ netting is made out of wide-meshed high-density polyethylene in which the insecticide (permethrin) is incorporated directly into the fibre at a 2% weight/weight concentration (corresponding to 1 gram/m^2 surface concentration). The extensive laboratory and field experience with Olyset™ nets are comprehensively reviewed in a WHOPES document [8], along with key specifications. Apart from their long-lasting effect Olyset™ nets are also very strong because of their thick fibres (equivalent to 180 deniers) and the strength of high-density polyethylene. As a result they are attractive for use in rural areas where ordinary 75–100 deniers polyester nets might not last for more than two to three years [9,10].

While the net's strength makes it very attractive, especially for rural users, the stiffness and "plasticky" feeling of the Olyset™ netting may be perceived to be less attractive to some users. The larger mesh size (4 mm as opposed to the usual 1.6 mm) designed for better ventilation can be also perceived by users as offering less protection against mosquitoes. In addition, the price of Olyset™ nets has so far been well above that of polyester nets, and it is not clear whether users will be willing to pay more for the long-lasting insecticidal effect and the stronger wear-resistance. So far only one study has been conducted on the willingness-to-pay for Olyset™ nets and it has been inconclusive [11].

In Tanzania, Olyset™ nets were distributed between December 1994 and early 1995 in Mbwawa village in Kibaha District (Coast Region) [12] and Mvumi village, Dodoma District [13]. Here we report a follow-up survey of these nets carried out in July 2002 with regard to their presence, insecticide dosage and bioassay efficacy. This setting offered an excellent opportunity to assess the long-term value of these nets, 7 years after their introduction in a rural African setting. Taking advantage of the increased availability of polyester mosquito nets in Tanzania since the late 1990's, we were also able to make a direct comparison of the desirability of Olyset™ nets in comparison with ordinary polyester nets, since both types of nets were familiar to most habitants of these villages.

Methods

Study area and population

Approval for this study was obtained from the ethical committees of the Ifakara Health Research and Development Centre and the National Institute of Medical Research in Tanzania (Ref: NIMR/HQ/R.8a/Vol. VII/114), and of the Swiss Tropical Institute in Basel, Switzerland.

Two villages where Olyset™ nets had been distributed from 1994 to 1995 were selected for the study. In both settings the weather pattern is characterized by a dry season and a rainy season from December to April.

Mbwawa is a rural village located about 60 km West of Dar es Salaam and 8 km north of the main Tanzanian-Zambia highway. The population belongs to the Zaramo tribe and consists of 1690 individuals in 399 households whose main occupation is small-scale farming of maize, plantains, tomatoes and other fruits. Parasite rate in children under 10 years was 75% (caused nearly always by *Plasmodium falciparum*) and the entomological inoculation rate peaked at 7.4 infective bites per night during the main transmission season [12].

Mvumi Mission is a large rural village situated 40 km south-east of Tanzania's capital Dodoma with a current population of about 11,576 distributed among 2,315 households. Inhabitants of Mvumi are mainly Wagogo who are small-scale farmers. Crops in this area are sorghum, millet, maize, groundnuts and grapes. There is a Mission Hospital in Mvumi [14]. In a cross-sectional survey carried out in July 1994 the malaria prevalence was found to be 57% in children under 10 years, with *Plasmodium falciparum* accounting for 63% of positive slides [13].

Mosquito net distribution

Mbwawa

The only source of Olyset™ nets produced by Sumitomo Chemicals Co. Ltd. (Japan) has been the distribution of free nets in December 1994 in the frame of a scientific trial

[12]. In total 1,300 nets were distributed, with one to three nets being given to each household. The nets were of blue colour and had a size of 1.1 × 1.8 × 1.5 metres. Since the expansion of a large-scale social marketing project (SMITN) to the Coastal Region in the late 1990s and the general expansion of the commercial market for nets, polyester mosquito nets became largely available for sale in the area. No coverage figures were available before the present study.

Mvumi

As a response to the increase in malaria cases in the region a total of 3,900 Olyset™ nets of the same size as above were distributed by the District Malaria Control Unit to villagers between January and March 1995. A further 450 nets were released between January and April 1996 [13,15]. In the present study only the nets distributed in early 1995 were followed up. Nets were given out at the highly subsidised price of TSh. 800 (approx. USD 1.5 in 1995) per net. In 1998, three years later, the SMITN social marketing project was launched in Dodoma Region and Mvumi was one of the pilot villages where different distribution strategies were tried out. Two types of polyester nets, bundled with deltamethrin tablets branded *Ngao*, were sold in the village through the project. One of the nets (brand *Lea Mwana*) was sold by the Hospital's mother and child clinic at a subsided price of TSh 2500 (USD 3 in 1998) to pregnant women and children under 5 years. This net had a blue colour similar to the Olyset™ net and measured 1.5 × 1.8 × 1.8 metres. The second net (brand *Njozi Njema*) was smaller (1.2 × 1.8 × 1.8 metres), green and sold for TSh 3500 (USD 4.2 in 1998) at the hospital pharmacy and local shops to the general population. From 1998 onwards there was, therefore, good access to polyester nets.

Household questionnaire

In Mvumi a list of households which had received Olyset™ nets in 1995 was provided by the Village Health Officer. Households belonging to eight different parts of the village were randomly selected from the list until a total of 50 households were obtained in which the occupants still possessed at least one Olyset™ net. Tracking fifty nets allowed us to assess basic net parameters with an acceptable precision, while not over-stretching field capacity in this labour-intensive follow-up. Households which had been given an Olyset™ net but did not have it anymore were also interviewed using a shorter version of the questionnaire in order to find out why this was so. A similar two-step random sampling approach was used in Mbwawa.

Once permission had been secured from the village authorities and consent obtained from a senior household member, a structured questionnaire was applied. The first part of the questionnaire assessed the presence, current state and use of the Olyset™ net(s), as well as its(their) re-treatment with insecticide.

The second part of the questionnaire assessed the opinion of people with regard to the advantages and disadvantages of Olyset™ nets compared to ordinary polyester nets, the performance of the nets when new and at the time of study.

Finally, the preference for Olyset™ nets or other nets marketed in the village was assessed with the following hypothetical question: *if you had to buy a new net today and had the money for it, would you prefer to buy an Olysef™ net (Olyset™ net shown to the person) or such a net (two different polyester nets shown)? All these nets cost the same price. Please explain your choice*. In order to exclude net cost as a factor influencing the choice of net, interviewers made a strong point in stating that all nets presented to the respondent had the same price. In the case of Olyset™ nets this was possible since Olyset™ nets were not on sale at that time. Two of the most frequently sold polyester mosquito nets available on the market on each study site were presented along with a new Olyset™ net, all in their original packaging. Since the polyester nets were not pre-treated but sold with an insecticide treatment kit, the Olyset™ net was offered with an insecticide kit as well.

Olyset™ net sampling and testing

Every tenth household interviewed was offered a new large, white polyester insecticide-treated net plus three insecticide sachets for re-treatment in exchange for their used Olyset™ net. Hence, five Olyset™ nets were collected in each site. These nets were individually packaged in plastic bags and kept at room temperature until shipment for testing. Keeping them in a refrigerator or freezer was not deemed necessary since the nets had already been left for seven years at room temperature.

A first set of 50 × 50 cm samples from each of the 10 nets was sent to the manufacturer (Sumitomo Chemicals Co. Ltd.) for permethrin content assessment. Testing was performed following standard procedures outlined in a WHO document (WHO/IS/NI/331/2002). Standard three minutes exposure bioassays were also conducted on these nets, but unfortunately only with *Aedes aegypti* and results are not reported here.

A second set of samples was sent to the Agricultural Research Centre in Gembloux, Belgium, a WHO Collaborating Centre. In order to measure permethrin content on the surface of the yarn a 10 × 10 cm piece (corresponding to about 600 mg) was cut from each Olyset™ net sample, accurately weighed and introduced into a 100 ml conical flask. Thirty ml of acetone were added and the flask was shaken for one minute. The acetone extract was quantitatively transferred into a 50 ml volumetric flask. Two ml of an internal standard solution (diethylhexyl adipate) were added and the flask was filled up to volume with acetone. The extract was put into an injection vial and analysed by capillary gas chromatography with flame ionisation detection (GC-FID) for determination of permethrin using the internal standard calibration. In order to determine the permethrin content inside the Olyset™ yarn after the first acetone wash, the sample was cut into 2–3 mm pieces and homogenised. A sub-sample of 400 mg was accurately weighed and introduced into a 100 ml conical flask. Thirty ml of xylene were added and permethrin was extracted by heating under reflux for 60 minutes. The extract was allowed to reach ambient temperature and quantitatively transferred into a 50 ml volumetric flask. Two ml of an internal standard solution (diethylhexyl adipate) were added and the flask was filled up to volume with xylene. The extract was put into an injection vial and analysed as above.

Finally, bioassay results for *Anopheles sp.* were obtained from 20 × 20 cms samples sent to a WHO Collaborating Centre (*Laboratoire de Lutte contre les Insectes Nuisibles*) in Montpellier, France. Tests were done using standard WHO cones with a three minutes exposure time. In order to have an accurate exposure, batches of only five female mosquitoes (*An. gambiae*, Kisumu susceptible strain) were introduced in cones at a time. Ten repeats were done for each net sample (50 mosquitoes total). After testing, mosquitoes were grouped in plastic cups covered with netting with honey solution provided and maintained for 24 h at 30°C and 80% humidity. Percentage mortality was noted after 24 hours according to two criteria: "effective" mortality (i.e. mosquito looks dead and does not move any more, the endpoint in the standard WHO methodology) and "functional" mortality (mosquito still moves but in such a feeble and uncoordinated way that it would not survive in a natural environment). Knock-down (KD) rates were noted 60 minutes after exposure.

Data analysis

Quantitative data was summarized using proportions and means. Comparison of proportions between categorical variables was performed by a chi-squared test using STATA (STATA version 7, TX, USA). Fisher's exact tests of significance were obtained where appropriate. Comparison between quantitative variables (such as insecticide content) was done using simple linear regression. Means were compared by the non-parametric Kruskall-Wallis test. Significance was determined at the 5% level. Data was stratified by village when significant differences were found.

Results

Use and state of Olyset™ nets

Of the 103 households included in the survey that received Olyset™ nets from 1994 to 1995, only three did not possess these nets anymore. The reasons given by these three interviewees were that the net had either been given away, burned accidentally or destroyed in some other way. All following results pertain only to the 100 interviewees who still had at least one Olyset™ net and were likely to be using it. The mean age of the 100 informants was 49 years (range 20–85); 62 were female. At the time of interview most households (80%) possessed between one and three (mean 2.4, range 1–8) nets of some type. Possession of Olyset™ nets ranged from one to four in Mvumi (mean 1.6) and one to eight in Mbwawa village (mean 2.1). Only *Olyset™ net*s were possessed by all households recorded as having one net only.

Individuals were asked whether they were still sleeping regularly under Olyset™ nets. Ninety five percent of the household inhabitants still used the Olyset™ nets for mosquito protection and 94% said they had slept under their Olyset™ net the previous night. There was no difference in use by village (Fisher's exact test, $p = 1.0$). It is likely that the response on net use was biased upwards because of the interview situation but this was difficult to ascertain.

Only 33/100 (33%) said they had ever re-treated their Olyset™ nets with insecticide. In Mvumi, 29 out of 50 households (58%) claimed they had re-treated their nets, while only 4/50 (8%) households in Mbwawa said so ($\chi^2 = 29.1$, 2df, $p < 0.0001$). Most people able to recall when the net was re-treated indicated treatment within the past 2 years (16/33 or 48% of all re-treatments). In Mvumi, the higher re-treatment prevalence could be explained by the presence of an active social marketing project of ITNs since 1998 and by a free re-treatment campaign held in December 1998/January 1999. Given the small number of Olyset™ nets in the area in comparison to the number of ordinary polyester nets (requiring re-treatment) the programme had not produced differential messages targeted at Olyset™ net owners and this had led to these unnecessary re-treatments. Reported re-treatment did not correlate with any of the laboratory measures, neither with the chemical analysis of insecticide on the surface, nor with the bio-assay results (results not shown).

One Olyset™ net per household was examined to ascertain its condition. Some were in good condition, having no hole to two holes (7 households). The majority (55%) of Olyset™ nets had between 6–15 holes over 2 cm in diameter (mean 13, range: no holes to 70 holes). Several nets had lost their original light blue colour and had turned grey to almost black due to the fumes of the fires inside homes (Figure 1). Many holes clearly resulted from burns

Figure 1
Olyset™ net used at home, Mvumi Mission village, Tanzania. Note the colour change of the net from light blue to a greyish colour due to dust and fumes inside the home. The net shows few holes.

rather than tears. The burning of nets is an important safety consideration and it is encouraging that none of the observed nets seemed to have burned for longer than it takes to create a hole of a few cm in diameter.

Preferences

From a closed list, the household informants were asked to enumerate reasons why they thought Olyset™ nets were good or not (Table 1). Initially, respondents were asked about how the nets worked when they were new. The main perceived advantages of Olyset™ nets were their durability, protection from mosquito bites, the reduction of mosquitoes and other insects and the subjectively perceived reduction of malaria episodes. In Mvumi, people were adamant that ticks infesting houses were killed or repelled by the "strong" insecticide of the new Olyset™ nets. The most important disadvantage expressed by the people was the small size of the Olyset™ nets. In Mvumi, people were also concerned that the mesh size could be too big and could allow entry of mosquitoes.

Further questions were asked to evaluate the effectiveness of Olyset™ nets at the time of the interview. Of the 94 individuals who responded, 87 (93%) said that currently Olyset™ nets did not kill or reduce the number of mosquitoes. To some extent this is reflected by the low mortality rates measured in the bio-assays (see below). When asked if currently Olyset™ nets protected from mosquito biting, 41/86 (48%) responded affirmatively, 44/86 (51%) denied it and 1 did not know. For both questions it was

Table 1: Advantages and disadvantages of Olyset nets according to people's responses (n = 100 when unstratified, n = 50 when stratified by village).

Reasons*	Yes n (%)	No n (%)	No contribution n (%)
Durability			
Kibaha Mbwawa	50(100)	0	0
Mvumi	44 (88)	1(2)	5(10)
Reduces/kills mosquitoes	78 (78)	0	22 (22)
Keeps mosquitoes from biting	86 (86)	0	14(14)
Reduces malaria	68 (68)	0	32 (32)
Reduces/kills other insects			
Kibaha Mbwawa	38 (76)	0	12(24)
Mvumi	46 (92)	0	4(8)
Good mesh size			
Kibaha Mbwawa	4(8)	4(8)	42 (84)
Mvumi	14 (28)	12(24)	24 (48)
Good net size (No = size too small)	4(4)	75 (75)	21 (21)
Looks nice	12(12)	0	88 (88)

* Variables are stratified by village when the difference between villages is statistically significant ($p < 0.05$)

not possible to assess the correlation between individual responses and the corresponding laboratory results because the numbers were too small. The interviewees estimated that the insecticide on the new Olyset™ net lost its effectiveness within 6 to 24 months. These results on perceived biting reduction are difficult to interpret because no difference could be made between *Anopheles sp.* mosquitoes and the more aggressive and pyrethroid-resistant *Culex quinquefasciatus*.

Direct comparison between Olyset™ nets and polyester nets

The individuals interviewed were asked which net they would choose if they had the money to buy them and if the price were the same. Overall, the Olyset™ net was preferred by 51/100 (51%, 95%CI = 41–61) of the respondents, the green polyester net by 41/100 (41%, 95%CI = 32–51) and the white/blue polyester net by only 8/100 (8%, 95%CI = 4–15). Reasons for preference were also elicited (Table 2). The total number of individuals recorded for each reason differs because not every possible answer was given by all the respondents. The main reason for choosing an Olyset™ net was durability of the netting and to a lesser extent the "strength" and persistence of the insecticide. The green polyester net was very popular and one of the important reasons for choosing it was its dark green colour, which masks the dirt produced by smoke and dust in the household. The small mesh size of polyester nets was also preferred.

Laboratory testing

All key results from the tests performed in the laboratory are presented in Table 3.

The average permethrin content measured in Gembloux was 6622 mg/Kg, while the average result from Sumitomo was slightly higher: 8120 mg/Kg. Therefore, 33% (Gembloux) or 41% (Sumitomo) of the initial insecticide dose (20,000 mg/Kg) was still present, confirming that Olyset™ nets are truly long-lasting. For individual nets there was a good correlation between measurements carried out in Gembloux and those in Sumitomo: $r^2 = 0.87$ (95%CI = 0.52–0.97). In both centres a large variability in insecticide content was found, with a high:low ratio of 5.2 (13328/2552) in Gembloux and of 3.0 (12700/4200) by Sumitomo.

The work carried out in Gembloux clearly indicated that the insecticide was still very much concentrated inside the fibres: average inside:outside ratio = 18. However, there was a surprisingly large variability in this ratio, from 7 to 63. This variability was not explained by re-treatment of the nets, nor by a difference in re-treatment date (results not shown). There seemed to be a positive correlation between this inside:outside ratio and the total insecticide content if one outlier with the highest total insecticide content (sample 130) was removed from the analysis: $r^2 = 0.90$ (95%CI = 0.59–0.98).

Bioassay results indicated that knock-down rates at 60 minutes (KD60) were very high, with a single exception (sample 110 with the lowest insecticide content). Overall, "effective" mosquito mortality was rather low (mean 34%), while "functional" mortality was slightly higher (mean 50%). Only one net showed no more insecticidal activity (sample 110), although there was still a total of 2552 mg/Kg of insecticide present, and 324 mg/Kg on the surface.

Table 2: Reported reasons for preferring either Olyset nets or polyester nets in a direct comparison. 100 respondents, but not all gave answers for all reasons.

Type of net (size)	**Olyset (1.1 × 1.8 × 1.5 m)**	**Green polyester (1.2 × 1.8 × 1.8 m)**	**White/blue polyester (1.5 × 1.8 × 1.8 m)**
Reason for preference			
Durability	48	3	1
Colour	0	27	6
Mesh size smaller	0	20	6
To have a new net	0	7	0
Insecticide kills more mosquitoes	1	0	0
Net is larger	0	3	0
Insecticide strong/lasts longer	8	0	0
Material feels better	3	3	0

Table 3: Laboratory testing of Tanzanian Olyset samples.

3a chemical testing

Sample identification	**(1) Gembloux, Belgium (WHO Reference Centre)**				**(2) Sumitomo, Japan**
	Inside mg/Kg	Surface mg/Kg	Ratio Inside: outside	Total mg/Kg	Total mg/Kg
10	3225	280	12	3505	7200
20	2486	311	8	2797	5900
30	3671	189	19	3860	4800
40	5833	323	18	6156	8300
50	6170	349	18	6519	6700
110	2228	324	7	2552	4200
120	12422	197	63	12619	11700
130	12297	1032	12	13328	12700
140	5976	311	19	6287	8900
150	8348	258	32	8606	10800
Average for 10 nets	**6266**	**357**	**18**	**6622**	**8120**

3b Bio-assay testing

Sample identification	**(3) LIN, Montpellier, France**		
	KD 60 (%)	Effective mortality (%)	Functional mortality (%)
10	100	42	81
20	98	14	18
30	100	74	92
40	95	9	9
50	100	38	54
110	24	0	0
120	100	22	31
130	100	57	85
140	100	23	43
150	100	62	89
Average for 10 nets	**92**	**34**	**50**

No significant correlation could be found between any of the bioassay results and insecticide concentration. For this analysis only the results from Gembloux were used because they detailed insecticide content inside and outside the fibre, but similar findings were obtained with the Sumitomo results (data not shown). The correlation between total insecticide content and KD60 was very weak and not significant: $r^2 = 0.15$ (95%CI = -0.53–0.71). No correlation could be found between total insecticide content and "effective" mosquito mortality: $r^2 = 0.07$ (95%CI = -0.58–0.67), or functional mortality: $r^2 = 0.07$ (95%CI = -0.58–0.67). Similarly, no correlation was found between "effective" or "functional" mosquito mortality and insecticide content on the outside of the fibre: $r^2 = 0.04$ (95%CI = -0.61–0.65) and $r^2 = 0.06$ (95%CI = -0.59–0.66).

Discussion

This survey carried out over seven years after the distribution of Olyset™ nets in two rural Tanzanian villages, presents a very encouraging picture. Firstly, nearly all nets could be traced and this indicated their durability and their value to the population. Secondly, most of the Olyset™ nets were still in a physical condition in which they were effective in protecting against mosquito biting. The high reported use, the good physical appearance of the nets, as well as the high KD60 values obtained in bioassays with *Anopheles gambiae* suggest that their protective effectiveness was still good.

The general state of the Olyset™ nets after this very long period was much better than that of polyester nets reported recently by Erlanger *et al.* [10] in a similar rural area in southern Tanzania. In that study polyester nets of 75–100 deniers were found to be already in a very bad state after only two years of use. Durability was an important argument cited in favour of Olyset™ nets and hence this aspect might also be considered for polyester nets, perhaps by increasing significantly the strength of their fibres.

On the other hand, the Olyset™ nets were reported to be too small, with large mesh size and the preferred colour in this area was dark green, rather than light blue. In general, people who cook indoors or live in a dusty environment prefer dark coloured to white nets. The perceived lack of effect against mosquitoes after 6 to 24 months is interesting to note but difficult to interpret in terms of its relevance for malaria control, since no distinction could be made between biting by *Anopheles sp.* and by other non-vector mosquitoes.

Similar observations were made in Senegal after seven years of Olyset™ net use by villagers: good physical status of the nets, size too small, some concern with mesh size, and the perception of reduced insecticidal efficacy after two years (P. Guillet, personal communication). It is important to point out that at least two of these "negative" attributes (size and colour) could easily be changed. Even mesh size could be modified if this proved to be important for users. Now that Olyset™ nets are being manufactured in Tanzania there is a good opportunity to adapt this product to the requirements of the local market (A. Shah, personal communication). One can only speculate about the choice respondents would have made if the Olyset nets had been larger and dark green, but it is very likely that a higher proportion would have chosen the Olyset™ net in the direct comparison. Often customers buy preferentially a product they are already familiar with. In the present study, the 100 households owned many more Olyset™ nets (total 188) than polyester nets (total 33). However, almost all respondents would have been aware of the qualities of polyester nets because they were widely available at the time of survey; it is therefore unlikely that prior experience was substantially different for both types of nets.

One element that could not be investigated in this pilot study, but which will affect the popularity of Olyset™ nets is retail cost. The price sensitivity for ITNs was found to be high in most endemic settings [16] and it is unclear what premium people would be willing to pay for a more durable net with a long-term insecticide treatment. This is of special concern since the effect of the insecticide in not always well perceived [4] and hence the value attached to this is generally low. A recent study on the willingness-to-pay for Olyset™ nets was inconclusive [11].

After seven years of continuous use the insecticide content on most of the nets was remarkably high, with 30–40% of the original insecticide still present. Almost the same residual amount was found in 30 Olyset™ nets used for 7 years in Senegal, although the surface concentration was significantly lower (P. Guillet, personal communication). In the Tanzanian sample there was, however, a high net-to-net insecticide content variability for which no satisfactory explanation could be found. So far there has been no reported manufacturing problems which could explain this variability. It is possible that more in-depth studies on the use of individual nets would elucidate the factors which are responsible for the more or less rapid depletion in insecticide.

After seven years of continuous use, 9 out of 10 Olyset™ samples still showed a high knock-down rate at 60 minutes and an average mortality rate in mosquitoes in a standard bioassay. Other studies also reported a good insecticide remanence. For example, after 3 years of use by villagers in Côte d'Ivoire, Olyset™ nets were still fully effective in bioassays (over 80% mortality after 3 minutes exposure) and as effective as new Olyset™ nets when tested in experimental huts [17].

Conclusion

Olyset nets are currently one of only two LLIN recommended by WHOPES and the present study supports the confidence vested in this product. The findings highlight that (1) Olyset™ nets are much more durable than ordinary polyester nets, (2) their insecticide content and effectiveness persists for several years, and (3) the population appreciated them. Some of the reported drawbacks could easily be addressed by modifying the product in terms of colour, size and possibly mesh size. Provided the price is competitive, Olyset™ nets represent currently one of the best options for ITNs in rural malaria-endemic settings.

Author's contributions

AT participated in the design and coordination of the study, carried out the field work and data collection, performed statistical analysis of the data collected and drafted the manuscript. GM participated in the field work and data collection and contributed to the writing of the manuscript. AT participated in the field work and data collection and contributed to the writing of the manuscript. HM provided logistic support and contributed to the writing of the manuscript. SD carried out the bio-assays and contributed to the writing of the manuscript. CL conceived the study, and participated in its design and coordination, performed statistical analysis and drafted part of the manuscript.

Acknowledgements

We thank the people of Mvumi and Mbwawa and their local authorities for their excellent cooperation, especially Mr A. Chuih, health assistant and Mr. D. Kamozora and Mr. E. Mziwanda, district health officers. We would also like to thank Dr. Pierre Guillet (WHO, Geneva) for valuable discussions and comments on the present manuscript; Mr. T. Itoh (Sumitomo Chemicals Co. Ltd., Japan), Mr. O. Pigeon (Agricultural Research Centre in Gembloux, Belgium) and Mr J.-M Hougard (LIN Montpellier, France) for performing the laboratory testing, and WHO for financial support in the performance of the bioassays and chemical analysis. Lastly, a word of thanks to the field team members S. Msagwa, D. Shamba, and A. Abdi. This paper is published with the permission of the Director-General of the National Institute for Medical Research (NIMR) in Tanzania. This work was supported financially by the Swiss National Science Foundation and the Swiss Tropical Institute in Basel, Switzerland.

References

1. MOH: **Ministry of Health. National Malaria Medium-term Strategic Plan, 2002–2007.** *Malaria Control Series 8* Dar es Salaam, Tanzania; 2002.
2. Lengeler C: **Insecticide-treated bednets and curtains for preventing malaria.** *Cochrane Database Syst Rev* 2004:CD000363.
3. Zimicki S: **Promotion in sub-Saharan Africa.** In *Net Gain, a new method for preventing malaria deaths* Edited by: Lengeler C, Cattani J, deSavigny D. Ottawa and Geneva: IDRC and WHO; 1996:111-148.
4. Minja H: **Introducing insecticide treated mosquito nets in the Kilombero Valley (Tanzania): socio-cultural dimensions.** *PhD thesis* University of Basel, Department of Epidemiology and Public Health, Swiss Tropical Institute; 2001.
5. Armstrong-Schellenberg JRM, Minja H, Mponda H, Kikumbih N, Mushi A, Nathan R, Abdulla S, Mukasa O, Marchant T, Tanner M, Lengeler C: **Re-treatment of mosquito nets with insecticide.** *Trans R Soc Trop Med Hyg* 2002, **96:**368-369.
6. Hanson K, Worrall E: **SMITN 2, Tanzania: end-of-project household survey analysis.** *Malaria Consortium* London, UK; 2002.
7. Guillet P, Alnwick D, Cham MK, Neira M, Zaim M, Heymann D, Mukelabai K: **Long-lasting treated mosquito nets: a breakthrough in malaria prevention.** *Bull World Health Organ* 2001, **79:**998.
8. WHOPES: **Olyset net. Report of the fifth WHOPES working group meeting.** [http://www.emro.who.int/rbm/Background%20documents/5thWHOPESWGmeeting.pdf.pdf].
9. Erlanger T: **Field issues related to insecticide-treated nets in Tanzania.** *MSc Thesis. University of Basel and Swiss Tropical Institute* 2002.
10. Erlanger TE, Enayati AA, Hemingway J, Mshinda H, Tami A, Lengeler C: **Field issues related to effectiveness of insecticide-treated nets in Tanzania.** *Med Vet Entomol* 2004, **18:**153-160.
11. Mubyazi GM, Bygbjerg IC, Massaga JJ, Barongo V, Kamugisha ML, Mdira KY, Njunwa KJ: **Willingness to pay for Olyset Bednets, Community perceptions and health seeking behaviour in relation to malaria in Korogwe and Muheza districts, north-eastern Tanzania.** *Report submitted to Sumitomo Chemical Company (Japan) and WHO* 2002.
12. Njunwa KJ, Kilimali VAEB, Marero SM, Msuya FHM, Pilyimo R, Kamuzora D: **Permethrin incorporated bednets, 'Olyset net', reduce malaria transmission after twelve months of their use in three villages of Kibaha District, Coast Region, Tanzania.** *Report from Sumitomo chemical Co Ltd. Japan. Dar es Salaam, Tanzania* 1996.
13. Chuih A: **Malaria control activities in Mvumi – Dodoma Rural from 1994 to July 1996.** *District Medical Health report, Dodoma rural District. Dodoma, Tanzania* 1996.
14. Talbert A: **Survey on Mvumi bed net scheme conducted May 1997.** *Report. Mvumi, Dodoma rural, Tanzania* 1997.
15. MCP: **Malaria control project – Mvumi village: Report of activities 1993–1996.** *Malaria control project report, Dodoma rural District. Dodoma, Tanzania* 1996.
16. Kikumbih N: **Economic analysis of social marketing and commercial sector insecticide treated net delivery models in rural communities of Tanzania.** *PhD thesis. University of London, London School of Hygiene and Tropical Medicine* 2002.
17. N'Guessan R, Darriet F, Doannio JM, Chandre F, Carnevale P: **Olyset net efficacy against pyrethroid resistant *Anopheles gambiae* and *Culex quinquefasciatus* after 3 years' field use in Côte d'Ivoire.** *Med Vet Entomol* 2001, **15:**97-104.